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TITLE: Acquisition of a Magnetic Resonance Imaging System for Research on the Neural Basis of Human Cognition

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13. Abstract ***(Maximum 200 Words)*** *(abstract should contain no proprietary or confidential information)*

From August, 15, 2001 through August 14, 2002 a facility for housing the 3T fMRI unit was constructed, the 3T MRI unit installed and the essential accessory items (stimulus/response computers, digital projection system, eye-tracking system, auditory system) integrated into the MRI system and made operational and initial, high quality human and non-human subject data have been obtained. An image analysis laboratory was equipped and made operational; this lab has six workstation-level computers for data processing and analysis. A large scale server (with 4 TB of tape storage) and local area network were installed to support the image analysis and data processing functions. A radio frequency (RF) coil lab was equipped and is in operation for designing and building custom MRI coils. A MRI system simulator was installed and modified to give full functionality for acclimating subjects and testing protocols prior to actual fMRI use. The primary support staff for the fMRI facility has been hired. Three workshops on fMRI, RF coil construction and fMRI data processing have been held for training the research staff at the UO in the technology of fMRI. Protocols for cognitive studies with fMRI have been approved and initial human subject studies are now underway.

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Introduction:

The main objectives of the research are to apply fMRI to investigate (a) the fundamental mechanisms and systems essential to processing, localizing and attending to specific events and stimuli in complex environments, (b) the neural systems important for motor control, sensory-motor integration and learning, (c) the processes of spatial attention and spatial 'working memory' and (d) the integration of fMRI results (having high spatial resolution) with electrophysiological data (ERPs and single cell measurements) having high temporal resolution and the integration of fMRI data with white matter 'tractography' (diffusion tensor MRI).

Body:

In the twelve month period (August, 2001 to August, 2002) the primary accomplishments are the completed construction of the facility for housing the fMRI unit, the delivery and installation of the fMRI unit, the successful integration and implementation of the stimulus response systems, eye-tracking system, subject physiologic monitoring system, the set up of the image analysis laboratory and the RF coil laboratory and the acquisition of initial structural and functional MRI data from human and non-human subjects. All of these were fundamentally necessary steps to reach the level of performing the research studies outlined in the Statement of Work. The MRI unit has been operational since mid-March of 2002 and the other ancillary equipment integrated and operational since late June of 2002.

With respect to the human studies of brain systems and mechanisms, initial human subject images are provided in the appendix. High quality 3-D structural images with good gray-white matter differentiation are routinely obtainable with the 3T system (See Figure 1). These structural images typically have 1 millimeter isotropic resolution. Structural images (2-D) with a so-called 'T2' contrast are also routinely obtainable with an in-plane resolution of 500 microns (See Figure 2). High definition MR 'angiograms' are also feasible with the system and can be used to map larger blood vessel locations to remove potential contributions of such vessels to the fMRI results (See Figure 3). Functional MRI data from both somatosensory tasks (finger tapping for example) and purely cognitive tasks (solving arithmetic calculations versus recalling lyrics to songs) have been obtained on a regular basis (See Figure 4).

With regard to the animal studies for auditory and visual processing, three custom-designed RF coils have been built and tested. Images from the coil designed for studies in the owl are provided (See Figure 5) and initial images from primates using the 3T MRI unit are also include in the appendix (Figure 6).

An additional four pages of pictures are provided in the appendix showing the construction, system installation and set-up of the MRI system. Also a picture of a lab-built MRI coil is provided in this portion of the appendix.

Interdisciplinary research training is also a primary component of the scope of work. The fMRI facility has already conducted three workshops for the faculty and research staff at the University. One was a workshop on the basics of fMRI, another on the design and construction of RF coils, and the third on the use of specific software tools for the analysis of fMRI data.

Ground work for the implementation of electrophysiological data acquisition simultaneously with fMRI has been done. Circuit designs for filtering the MRI-induced signals in the electrophysiology leads are to be provided by Professor Nikos Logothetis of the Max Planck Institute (Tubingen, Germany) and these will be constructed and tested for use in both human and primate studies.

To date, six human subject use protocols for fMRI studies have either been approved or are in the process of review for approval by the University's Human Subject Compliance Committee.

Finally, work on the development of automated and semi-automated edge-detection software has been done in the past year. The objective is to remove and/or reduce user bias and selection in the data analysis process and to provide quantitative and robust methods for image segmentation and parcellation. Also, a fully functional program for the conversion of the industry standard 'DICOM' image files (that most MRI devices generate) to other commonly used image files in data analysis programs has been accomplished.

Key Research Accomplishments:

- Demonstration of state-of-the-art human and non-human subject MRI results on a routine, day-to-day basis
- Establishment of the capability to design and fabricate purpose-built MRI (RF) coils on an 'everyday' basis
- Implementation of the MRI-controlled triggering of visual stimuli to subjects in the MRI magnet and acquisition of fMRI data from this; the acquisition of initial human subject protocol fMRI results

Reportable Outcomes:

Funding Applied for: NIH and NSF grant and grant renewal submissions from Drs. Neville, Dassonville, Tucker, Nunnally and Dow have been made and are in progress of submission for October 1, 2002 and February 1, 2003 dates.

Research Opportunites Supported: Collaborative research into blood-brain barrier properties (Dr. Ed Neuwelt, Oregon Health Science University) has been initiated with support from this award; research opportunities with Electrical Geodesics Inc (Dr. Jeff Eriksen) and InVivoMetrics, Inc (Gary Tye) have also resulted from this award.

Conclusions:

The facility has only just become fully functional within the past eight weeks. Initial results have been obtained, but no study has been completed at this time.

Edge detection/image segmentation software that is virtually automated and free from user bias has a number of potential scientific and medical uses as a product. Quantitative assessment of any form of image data (MRI, CT, ultrasound, x-ray, optical imaging – to name the most obvious) whether from research or medical applications has many potential uses. Rapid image segmentation and parcellation could aid in the more timely review of medical imaging data and reduce the number of errors in the 'reading' of diagnostic images. This same software can be used for better treatment planning and assessment of treatment outcomes.

References: none

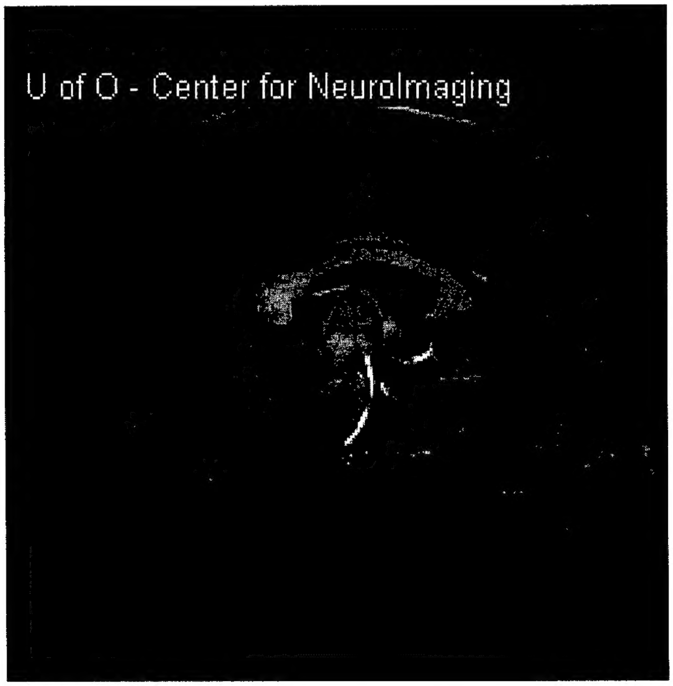

Figure 1. Sagittal plane multiplanar reformat image from a 3-D MRI acquisition.

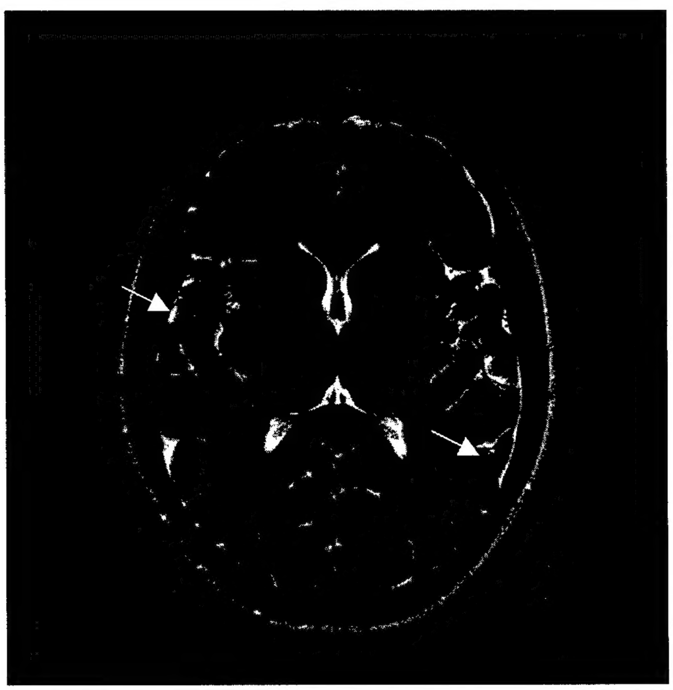

Figure 2. 'T2' copntrast image with 500 micron in-plane resolution. Note the small blood vessels seem as darker objects within the brain on both the right and left sides of the image. Also note the very crisp gray and white matter differentiation.

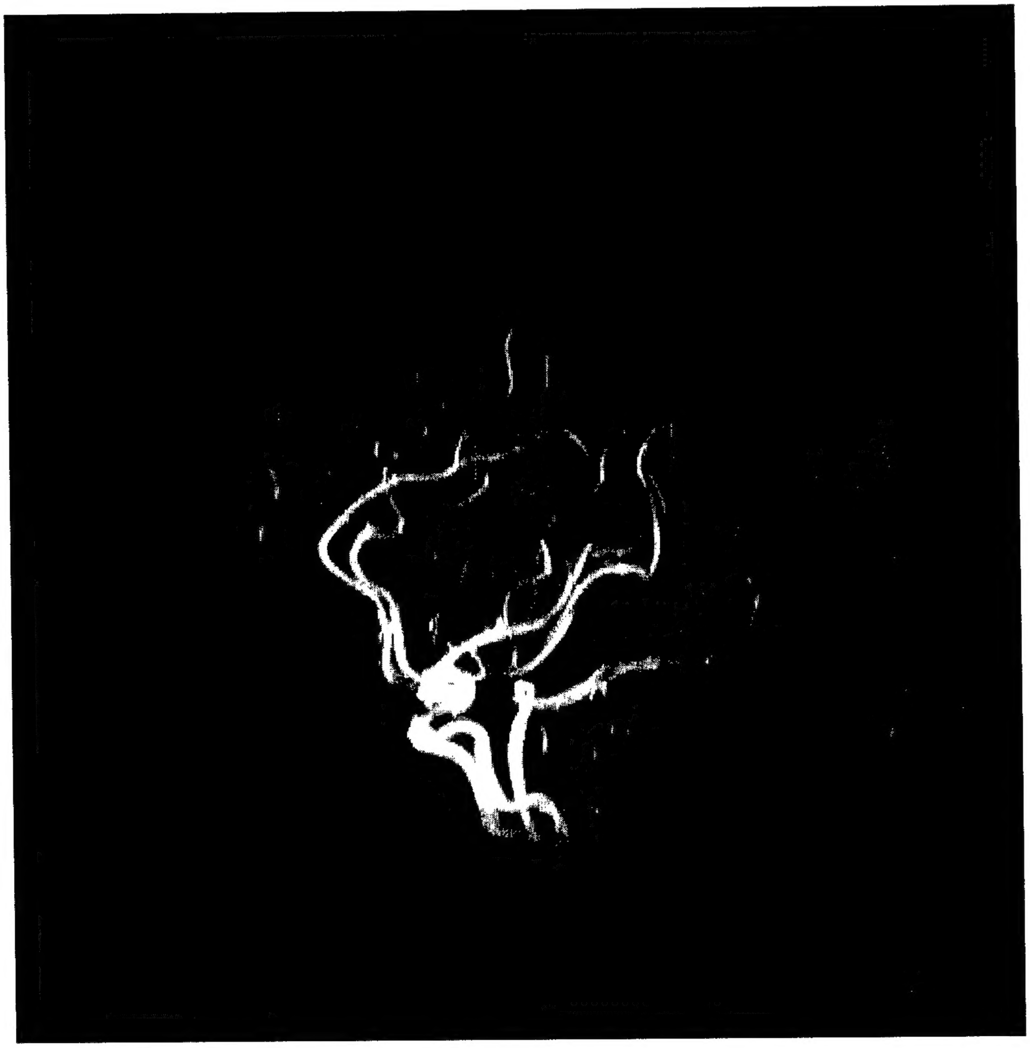

Figure 3. MR angiogram from the 3T Siemens Allegra at the U of O. Human subject - no contrast material used. Note the number of smaller vessels seen on the image.

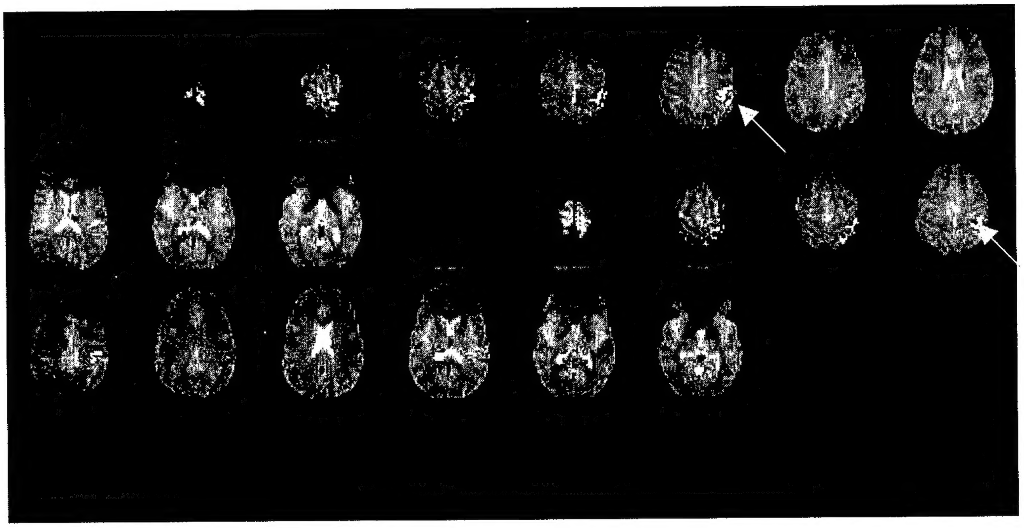

Figure 4. Processed fMRI data from finger tapping exercise. The total time to acquire the data was 6 min 44 sec. Images are acquired in an 'interleaved' manner. A total of 22 slices covering of most of the brain were acquired every 2 seconds. The image resolution is approximately 3 mm. Areas of activation appear as brighter (arrows).

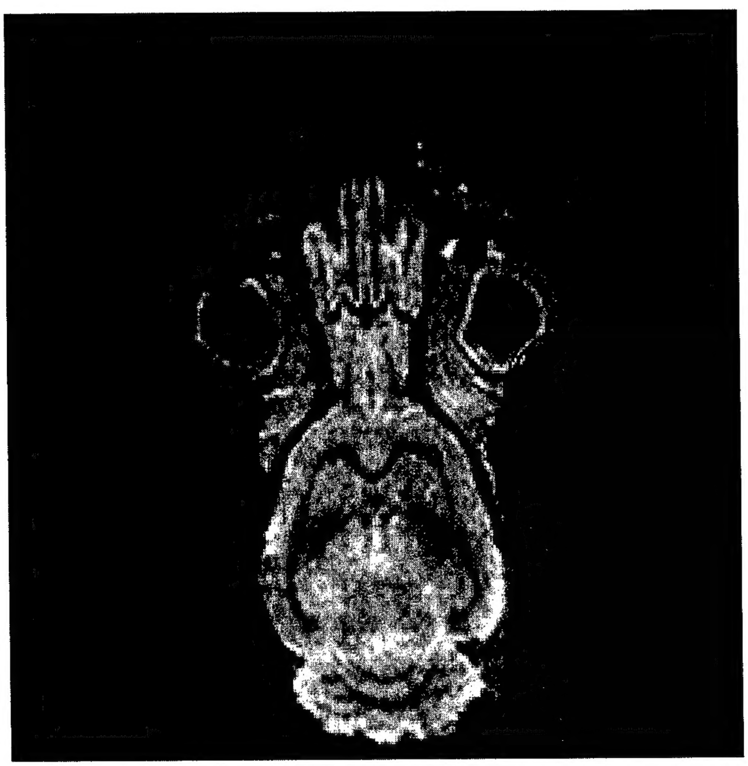

Figure 5. Test images of a rat head using the 'owl' coil. The in-plane resolution of the image is approximately 200 microns. A full 3-D image set was acquired in 7 minutes at this resolution.

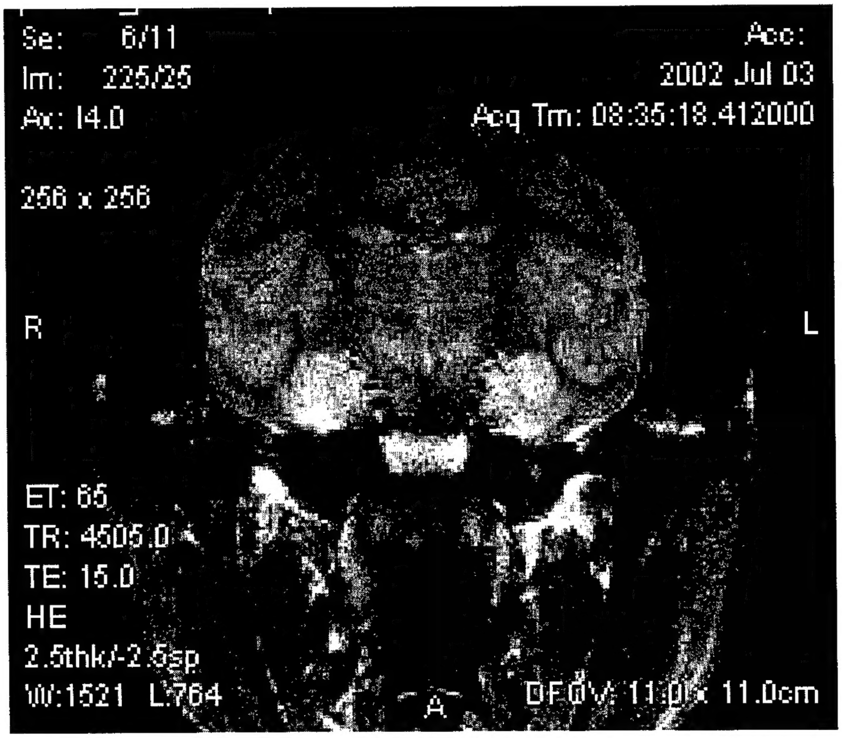

Figure 6. Image ('proton density' contrast) of a live primate brain with 400 micron in-plane resolution. Good gray-white matter contrast is obtained with high spatial resolution. The 2-D image data of the whole brain took less than ten minutes to obtain.

Imaging

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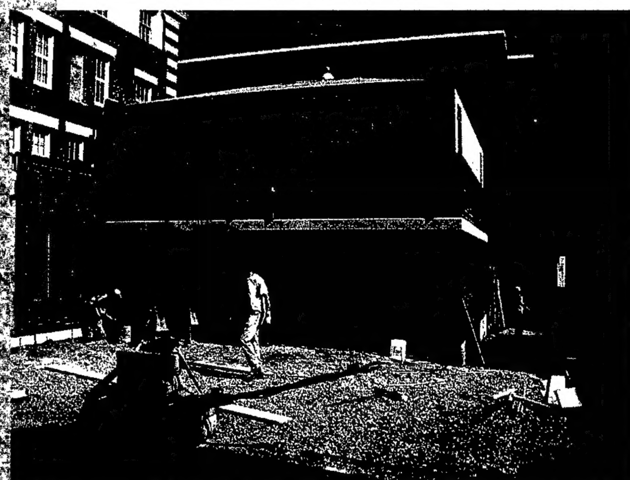
Successes to Date



Late stage construction of facility

Imaging

TATRC

Successes to Date

Late stage finish-out of the RF shielding in the magnet room

Imaging

Successes to Date

Installation of the 3 T magnet in the specially constructed room

Imaging

Successes to Date

fMRI system control area, magnet can be seen through the window

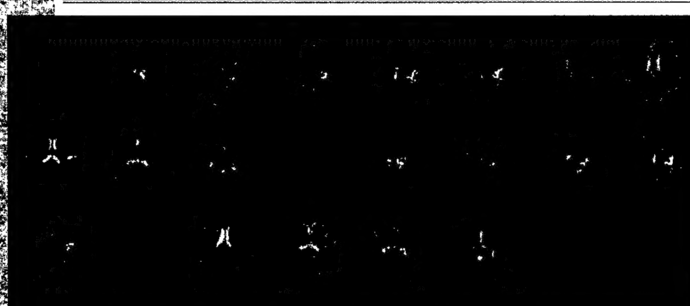
Imaging

Successes to Date

Installation of the 3 T magnet in the specially constructed room

Imaging

Successes to Date



fMRI results from the Univ. of Oregon's 3 T system. These images show the brain activation of the motor strip associated with the activity of finger tapping. Total time to complete the fMRI measurement = 5 minutes, 30 seconds.

Imaging

Successes to Date

RF coil lab

Imaging

Successes to Date

MRI (RF) coil designed, built and tested at the facility. Suitable for brain imaging in small animals.